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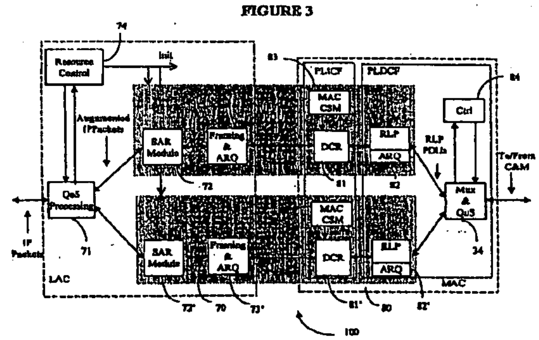
(54) **Data link layer quality of service for UMTS**

(57) A Data Link Layer (DLL) (20) protocol for direct support of the Internet Protocol (IP) networking in the Universal Mobile Telecommunications System (UMTS) (100), is provided. The disclosed Data Link Layer (20) comprises a Radio Link Control (RLC) (70) sublayer and a Medium Access Control (MAC) (80) sublayer. At a transmit end, as well as at a receiving end of the UMTS wireless system (100), a plurality of Quality of Service (QoS) planes (1...n) are created according to IP QoS requirements. At the RLC level, each QoS plane (1...n) comprises a Data-RLC (14-1,..., 14-n) and a Control-RLC (12-1, ..., 12-n). The QoS planes (1...n) are optimized to handle the QoS requirements of a corresponding Class of Service (CoS). At the transmitting end, the data packets received from the upper layers are directed to a QoS plane according to the particular QoS information they contain, and processed according to their particular QoS requirement. A Segmentation, Concatenation, and Reframing module (SCR) is used to generate variable size RLC frames (77; 77'), including multiframing. The variable size RLC frames (77; 77')are transmitted to the MAC sublayer (80) using logical channels (15). At the MAC sublayer (80), the RLC frames (77; 77') are multiplexed onto transport channels (25) based on their QoS requirements and transmitted to the physical layer for propagation to the receiving end.

FIGURE 3



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Description

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates generally to Data Link Layer (DLL) protocols, and more particularly to a DLL protocol for direct support of network layer protocol data services, i.e. the Internet Protocol (IP), for the Universal Mobile Telecommunications System (UMTS).

Description of the Related Art

[0002] Layered architecture is a form of hierarchical modularity used in data network design. All major emerging communication network technologies rest on the Open System Interconnections (OSI) layer architecture of the International Organization for Standardization (ISO), illustrated in Figure 1. In this architecture, a layer performs a category of functions or services. The OSI model defines a Physical Layer (Layer 1) which specifies the standards for the transmission medium, a Data Link Layer (Layer 2), a Network Layer (Layer 3), a Transport Layer (Layer 4) and Application Layers (Layers 5 to 7). Data Link Control protocols are used to mitigate the effects of impairments introduced by the physical transmission medium. A Data Link Control protocol is designed to deal specifically with the types of impairments found on the radio link and comprises mechanisms to deal with errors on the communications link, delays encountered in transmitting information, lost information, bandwidth conservation, and contention resolution.

[0003] The third layer is the Network Layer which implements routing and flow control for the network.

[0004] The fourth layer, Transport Layer, provides reliable and transparent transfer of data between end points. It also provides end-to-end error recovery and flow control. For the Internet based protocol model, the Transport Control Protocol (TCP) mainly corresponds to the Transport Layer of the OSI model.

[0005] Current wireless networks use layer 2-4 protocols designed specifically for the wired networks. However, there are some major differences between the wireless and the wired environment, resulting in important differences in the way these networks operate.

[0006] In a wired network the bit error rates are typically on the order of 10^{-9} or better, and errors and packet loss have a tendency to be random. Therefore, the wired transmission medium could be considered essentially error-free and the TCP data packets are lost mainly due to congestion in the intervening routers. Moreover, in a wired system the transmission channel has a constant bandwidth and is symmetrical, which means the characteristics of the channel in one direction can be deduced by looking at the characteristics of the channel in the other direction. Therefore, it is often easier to use a common link control protocols and to solve congestion problems by adding bandwidth.

[0007] On the other hand, in a wireless environment, most of these assumptions are no longer valid. The wireless channel is characterized by a high bit error rate. The errors occur in bursts that can affect a number of successive packets. Due to fading, low transmission power available to the User Equipment (UE), or the mobile station, and effects of interference, the radio link is not symmetrical and the bandwidth of a transmission channel rapidly fluctuates over time.

[0008] Furthermore, in a wireless environment, the amount of bandwidth available to the system is fixed and scarce. Adding bandwidth to the radio link may be expensive or even impossible due to regulatory constraints.

[0009] In addition, the issues in connection with increasing the transmission bandwidth are substantially different in the wireless environment. In a wired environment increasing the throughput is simply a matter of allocating as much bandwidth as possible to the connection. In a wireless environment, part of the bandwidth is used in error correction. More error correction means less payload. However, more error correction increases the probability of correct delivery without retransmissions. Thus, in the wireless environment increasing the end-to-end throughput may be obtained by reducing bandwidth assigned to payload and using the freed bandwidth for error correction.

[0010] The Data Link Layer (DLL) protocols available to date for wireless systems do not attempt to be inclusive as complete DLL protocols. Basically, off-the-shelf protocols intended for different media have been adopted for wireless systems. Even though some of those protocols are standardized, they are not very efficient for the wireless system. Also, some of the interactions between the non-wireless protocols and the communication system have caused a lot of complexities. For example, a point to point protocol (PPP) is currently used to conduct part of the functionality needed for the Data Link Layer (DLL). However, such a protocol imposes new limitations over the communication system. Moreover, for the DLL protocol to support the IP quality of service (IPQoS), the PPP encapsulation must be undone and this lowers the throughput.

[0011] Accordingly, there is a need for a specialized DLL protocol for a 3G wireless system which can satisfy the demand for advanced multimedia services in a UMTS environment, to support multiple concurrent voice, packet data, and circuit data services, each type of service having different QoS requirements.

SUMMARY OF THE INVENTION

[0012] According to one aspect of the invention a Data Link Layer (DLL) for direct support of a network layer protocol is provided. At a transmit end, as well as at the receiving end of a wireless communication sys-

tem, the DLL of the invention uses a plurality of QoS planes for processing the received data packets according to a particular QoS requirement. A QoS plane is comprised of a Data-RLC and a Control-RLC. According to the information in a received network layer data packet, a subflow processing module converts the received data packets into QoS oriented data packets and redirects same to the appropriate QoS plane. Each QoS plane or subflow, includes a segmentation, concatenation and refraining (SCR) module for generating radio link protocol data units (RLC PDUs), or RLC frames to be multiplexed and transmitted to the receiving end.

[0013] According to another aspect of the invention, a method for processing network layer protocol data packets for transmission over the UMTS wireless communication system, is provided. At a transmit end, as well as at the receiving end of the UMTS wireless system a plurality of QoS planes are created at the Radio Link Control (RLC) level of the wireless communication system for processing the data packets received from the network layers according to their QoS requirements, and to generate RLC frames be multiplexed and transmitted over the Physical Layer. The method comprises the steps of converting the received network layer protocol data packets into QoS oriented data packets according to the information contained in the received data packets; directing the QoS oriented data packets to a corresponding QoS plane, each QoS plane having its dedicated Data-RLC and Control-RLC instances, as well as Radio Resources Control; at the RLC level, dividing the QoS oriented data packets in smaller size sequence frames and reassembling a plurality of sequence frames to form RLC frames; at the MAC level, receiving the RLC frames, multiplexing, and regulating their delivery to the physical layer over transport channels.

[0014] According to another aspect of the invention, a method for processing network layer protocol data packets for transmission over a wireless communication system is provided. A plurality of QoS data planes are created at the Data Link Layer level of the wireless communication system for processing the data packets received from the network layers according to a Class of Service (CoS), and to generate RLP PDUs to be transmitted over the Physical Layer. The method comprises the steps of converting the received network layer protocol data packets into QoS oriented data packets according to the information contained in the received data packets; directing the QoS oriented data packets to an appropriate QoS data plane, each QoS data plane having its dedicated LAC and MAC instances; at the LAC level, dividing the QoS oriented data packets in smaller size sequence frames and encapsulating a plurality of sequence frames to form HDLC-like LAC frames; at the MAC level, receiving the LAC frames and regulating their delivery to the radio link protocols (RLPs) and converting the LAC frames into protocol data units (RLP PDUs).

[0015] Advantageously, the Data Link Layer according to the invention, enables direct support of the IP networking and IP Quality of Service (IP QoS) in the wireless UMTS system by introducing the QoS planes to handle different QoS requirements demanded by various advanced multimedia services.

[0016] The Data Link Layer according to the present invention removes the need for other non-wireless data link protocols, such as PPP, to connect to the IP.

[0017] Beneficially, a Radio Link Control (RLC) sublayer supported by the preferred embodiments of the present invention is capable of interfacing with existing non-wireless Data Link protocols.

[0018] Other aspects and features of the present invention will become apparent to those skilled in the art upon review of the following description of specific embodiments of the invention in conjunction with the accompanying figures.

[0019] The Summary of the Invention does not necessarily disclose all the features essential for defining the invention; the invention may reside in a sub-combination of the disclosed features.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The invention will now be explained by way of example only and with reference to the drawings.

Figure 1A shows the OSI layers in general;
Figure 1B is a sequential timing chart for the transmission operation according to a conventional ARQ protocol;
Figure 1C is a transmission frame structure according to the conventional ARQ protocol;
Figure 2 shows the OSI layers for a wireless communication system according to the proposed TIA TR-45.5;
Figure 3 is a block diagram of the DLC protocol according to a preferred embodiment of the invention;
Figure 4 illustrates the mapping of the IP packets to RLP PDUs (frames) according to a preferred embodiment of the invention
Figure 5 illustrates the mode of operation of an improved dual mode Layer 2 ARQ protocol;
Figure 6 shows the radio interface protocol architecture used with UMTS;
Figure 7 is a block diagram of the Data Link Layer (DLL) protocol according to a preferred embodiment of the invention; and
Figure 8 illustrates the mapping of IP packets to RLC PDUs (RLC frames) according to a preferred embodiment of the invention.

[0021] Similar references are used in different figures to denote similar components.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0022] The following description is of a preferred embodiment by way of example only and without limitation to the combination of features necessary for carrying the invention into effect.

[0023] Throughout the description the term "Quality of Service" (QoS) refers to network layer protocol QoS which includes "best effort", "expedited delivery", and "assured delivery". A Class of Service (CoS) defined at the DLC layer includes a set of services that have substantially the same QoS requirements.

[0024] Figure 1A shows the International Organization for Standardization (ISO/OSI) reference model in general, and was described above. The layers are denoted with 20 (not shown), 30, 40, 50 and 60.

[0025] Figure 1B shows a typical data transmission, using Automatic Repeat Request (ARQ), and Figure 1C shows a transmission frame structure for a conventional ARQ system. Figure 1B illustrates a transmitter Tx on the transmitting side of a wireless transmission system, a receiver Rx on the receiving side, and the transmission path. The transmission path is a wireless transmission channel established between the transmitting and receiving sides.

[0026] The ARQ frame 10 of Figure 1C comprises client information, denoted "information signal" 12, which is the data to be transmitted. An error detection code 13, such as a Cyclic Redundancy Checking (CRC) code is attached to the transmission data 12 by the ARQ transmitter Tx. At the ARQ receiver Rx, each frame 10 of the received signal is checked for errors using field 13, and Rx sends a re-transmission request signal back to Tx whenever an error is detected. In the case the frame is received without errors, Rx extracts the information signal 12 from frame 10 and the client information is delivered to the respective terminal.

[0027] Field 11 denotes "ARQ control data" in frame 10 indicates to Tx if the data have arrived at Rx with or without errors, and also identifies which frame has to be retransmitted.

[0028] Figure 1B illustrates transmission of eight consecutive frames, frame 1 to frame 8. In this example, frame 1 is received correctly by Rx, which sends Ack #1 (Acknowledgment, frame #1) to Tx. On the other hand, frame 2 is received with errors, and Rx sends NAK #2 (Negative Acknowledgment, frame #2) to Tx, which indicates that frame 2 must be retransmitted. In response to this NAK #2 signal, Tx retransmits frame 2, denoted with 2' on Figure 1B. Nak #2 is received during transmission of frame 4 so that the second frame 2' is retransmitted immediately after frame 4 and before frame 5. If frame 2' is again received in error, retransmission is requested again, in response to the NAK #2' signal, until frame 2 is received without errors, as indicated to Tx by Ack #2 signal.

[0029] Current second generation (2G) wireless systems are designed mostly to handle voice traffic, with some allowances for circuit-switched data. Later, packet data services were grafted onto the 2G systems but these are uniformly treated according to "best effort delivery" schemes. The type of RLP used in 2G systems is typically based on the generic service(s) available to the MS (Mobile Station), as for example voice services, packet data services, and/or circuit switched data services. The voice service may use a transparent RLP which does not provide error detection. The packet data service may use a non-transparent RLP which provides error detection and retransmissions. The circuit switched data service may use either a transparent or a non-transparent RLP.

[0030] Enhancements to the existing 2G wireless systems are currently under way, motivated by higher bandwidth and the need to handle a wider variety of services. Proposed standard TIA TR-45.5 supports a fully generalized multi-media service model, which allows virtually any combination of voice, packet data, and high speed circuit data services to operate concurrently. The TIA TR-45.5 will include a sophisticated Quality of Service (QoS) control mechanism to balance the varying QoS requirements of multiple concurrent Classes of Service (CoS).

[0031] Non-wireless Data Link Layer protocols(e.g. PPP), Network Layer protocols (e.g. IP), Transport Layer protocols (e.g. TCP), and the Application Layers are considered as "upper layer protocols" in the wireless protocol stack architecture, shown in Figure 1A.

[0032] In the third generation (3G) wireless communication systems, the Internet Protocol (IP) is selected as the preferred network layer protocol 41.

[0033] The IP packets (e.g. versions 4 and 6) include the IP Quality of Service (IPQoS) information. There are two main trends in the industry to support the IP QoS. The first method uses an end-to-end flow control. This method is called the Integrated Services (Int-Serv), and it uses a ReSerVation setup Protocol (RSVP) to pass the QoS request from the end system to each intermediate router along the data path. An admission control algorithm at each router along the path verifies the resources needed to provide the requested QoS. A policy control unit performs the administration. The Int-Serv approach results in lowering the throughput and it is somewhat complicated and not easily scalable. In the second method, the complexity is moved to the edges of the network, keeping the core simple. This scheme is named Differentiated Services (Diff-Serv). The traffic conditioning is done in a per-hop basis. The Diff-Serv method is preferred as it is easy to implement and scalable.

[0034] The Data Link Layer protocols proposed to date for the TIA TR-45.5 do not support IP 41 directly and therefore, other protocols such as PPP 42 are used, as shown in Figure 2. Obviously, these protocols impose additional restrictions on the wireless system in general.

[0035] Figure 3 shows the structure of the DLC layer 100 according to a preferred embodiment of the invention, which is designed to support IP networking without adding any limitations that are not related to the wireless systems. The new DLC layer 100 design according to the preferred embodiment of the invention may be viewed as an interface between the IP layer 41 and the Physical Layer 20 (not shown), and can accommodate a variety of Classes of Service (CoS) having different Quality of Service (QoS) requirements. It follows that the layers proposed in the ITU IMT-2000, i.e. the DLC layer functionality is divided into LAC sublayer 70, and MAC sublayer 80 which in turn includes the PLDCF and the PLICF sections.

[0036] The DLC protocol 100 according to the preferred embodiment of the invention is shown in Figure 3 and includes direct support for the IP protocol 41 and isolates the logical operation of the network from the Physical Layer 20 (not shown). As indicated above, the IP packets include the IP Quality of Service (IPQoS) information. The DLC layer 100 has a scheme to map the IPQoS requirements to DLC Classes of Service (CoS). Each CoS is separated inside the DLC protocol layer 100 and directed to a specific QoS data plane.

[0037] Figure 3 shows the structure of an enhanced DLC protocol architecture 100 according to the preferred embodiment of the invention, for two QoS data planes, namely QoS data plane 1 and QoS data plane 2, separated by a dotted line. It is however to be understood that the invention is not limited to two QoS data planes, and that more planes may run simultaneously in the DLC layer 30. Each QoS data plane is optimized to handle the QoS requirements of the corresponding CoS.

[0038] Figure 4 illustrates how the data is processed in the DLC protocol layer 100 and is described together with Figure 3.

[0039] A QoS processing module 71 of the LAC layer 70 is responsible for receiving the IP packets and extracting the IP QoS requirements included in the IP packets. IP QoS requirements are translated into QoS classes of service. The QoS processing module 71 also initiates a QoS data plane for each CoS through a Resource Control (RC) unit 74. Each QoS data plane include dedicated LAC and MAC instances.

[0040] An IP packet received by the QoS processing module 71 directly from IP block 41 of network layer 40 (shown in Figure 2), is denoted with 45. An optional length (LEN) indicator 47 is added to each packet 45 by the QoS processing module 71. The length indicator 47 is added to enable reconstruction of the original IP packet 45 by a Segmentation and Reassembly (SAR) module (not shown) at the receiving side. Similarly, the length indicator of the IP header can be used. In this case, the LEN indicator is not needed. The resulting packet 46 is called an "augmented IP packet".

[0041] Furthermore, based on the QoS classification obtained, QoS processing module 71 redirects the IP packets 45 to the proper QoS data plane. Packets without IP QoS classification are defaulted to a "best effort" QoS data plane. It should be noted that any network layer protocol other than the IP may be supported by including the corresponding functionality in the QoS processing module 71. There is at least one QoS processing module (not shown) for each Mobile Station (MS). Moreover, the receiving and the transmitting sides comprise identical QoS data planes.

[0042] A Segmentation and Reassembly (SAR) modules 72, 72□ is provided in each QoS plane. For example, SAR 72 is provided in QoS data plane 1, and SAR 72' is provided in QoS data plane 2. In this example, SARs 72 and 72' receive the redirected and augmented IP packets 46, or QoS oriented data packets having same Quality of Service (QoS) requirements.

[0043] SAR module 72 or 72' chops the augmented IP packet 46 to smaller size packets, which are more suitable for error recovery and retransmission. These smaller size packets are defined as "sequence frames", denoted with 74, 74', on Figure 4. The size of a sequence frame is variable and dynamically optimized for different QoS data planes based on the QoS requirements and the radio link conditions.

[0044] A start of message (SOM) bit field 75 and a sequence number field 76 are then added to the payload 46. A logic "1' for example in SOM bit 75 could be used to identify the start of a sequence frame 74, while the sequence number is necessary in the retransmissions of unsuccessful frames.

[0045] As a result, a number of smaller same Class of Service (CoS) sequence frames 74, 74', are presented by a respective SAR module 72, 72', to a Framing and Automatic Repeat Request (ARQ) module 73, 73'. A new level of error recovery (i.e. ARQ) is created at the LAC level to provide better connectivity and to prevent propagation of errors to higher levels. The sequence frames are then encapsulated in High-level Data Link Control (HDLC)-like frames 77, 77', in a respective Framing and ARQ module 73, 73'.

[0046] HDLC-like framing is used to separate individual sequence frames by means of "bit stuffing" operation within the payload and encapsulating by start and end flags. A 16 bit Frame Check Sequence (FCS) 79 is included for error detection and is used for ARQ protocols. The HDLC-like framing applied here does not use the address and control fields of the generic HDLC frames. The HDLC-like frames serve as LAC Protocol Data Units (LAC-PDUs), or LAC frames, as indicated on Figure 4. The maximum size of a LAC frame 77 is defaulted to be the same as the one for PPP, which is 1500 bytes. This maximum value is negotiable.

[0047] As discussed above, the sequence frame 74, 74', has variable length which can be dynamically adjusted by the transmitting side, based on the radio link conditions. This results in variable length LAC-PDUs.

[0048] The radio link conditions can be monitored in the following ways. If there are many negative acknowl-

edgments (NAKs) from the receiving side, or for a predetermined period of time no acknowledgment is received, then the LAC-PDU size could be lowered to enhance the error correction and the overall throughput. No negotiations take place between the transmitting and the receiving LAC instances and therefore, there is no need for over the air signalling.

[0049] The LAC-PDUs 77 are then delivered to the MAC instance 80 in the same QoS data plane. The point-to-point link connectivity of each QoS data plane is maintained by peer LAC instances at the transmitting and the receiving sides.

[0050] According to the invention, the IP layer 41 can sit on top of the new DLC layer 100 and the DLC protocol provides direct support for any network layer protocol with no need for any other protocol as an interface. This greatly reduces the limitations imposed by other protocols, which are not designed for the wireless systems.

[0051] Within each QoS plane, MAC sublayer 80 comprises the PLICF and PLDCF sections, as per TIA TR-45.5. A Dedicated/Common Router (DCR) 81 or 81', is controlled by the MAC Control State Machine (MAC CSM) 83, 83' to route LAC-PDUs to be carried over a dedicated or a common radio traffic channel. When a dedicated radio traffic channel is used, the PLDCF section includes a dedicated Radio Link Protocol (RLP) 82 or 82', as defined in TIA TR-45.5. The RLP 82 or 82', treats the incoming traffic from the DCR 81, or 81' as a byte stream and encapsulates the LAC-PDUs into 20 ms RLP-PDUs.

[0052] For the non-transparent RLP (as defined in the TIA TR-45.5 and the TIA/EIA/IS-707A), ARQ function is also provided at the MAC level. The RLP-PDUs which are received with errors will be retransmitted. The functions of the peer RLPs at the receiving side include the re-sequencing of the received PDUs to insure in-order-delivery to the MS/LAC sublayer. The RLPs used are designed for different classes of service (CoS). This adds another level of error correction and flexibility for optimizing a QoS data plane for a specific CoS.

[0053] A preferred embodiment of the present invention also provides an improved ARQ protocol at the MAC level with two modes of operations: a normal-mode (NM) and a burst-mode (BM). When in normal-mode, a Selective Repeat (SR) ARQ scheme is used. In burst-mode, a Stop-and-Wait (SW) ARQ scheme is used. Depending on the CoS or the QoS requirements, the ARQ protocol chooses to use either one of the SR or SW schemes.

[0054] The SR scheme provides highest throughput efficiency since the transmitter transmits frames continuously and only the corrupted frames are retransmitted. However, to operate in SR mode, an initialization handshake procedure is needed so that peer ARQ protocol entities are initialized, i.e. the frame sequence number is reset to zero, and the retransmissions buffer is cleared. The latency and bandwidth overhead introduced by the initialization procedures are undesirable if, for example, the traffic profile of the service consists of short data bursts with large inter-arrival time and consequently, the peer RLP entities need to be re-initialized after each idle period.

[0055] The SW scheme is used for short and infrequent data bursts. For the SW scheme, the transmitter stops and waits for acknowledgment from the receiver before sending out the next PDU. There is no need to synchronize the state between peer ARQ protocol entities. Therefore, when the SW scheme is used, no initialization procedures are needed as in the SR case, which reduces the associated latency.

[0056] As shown in Figure 5, a RLP entity is operating in one of the two modes, i.e., normal-mode and burst-mode. When the RLP entity is first activated, it transits from the NULL state to a default mode which is the burst-mode as shown at 91, where no initialization handshake is required. It should be noted that RLP protocols are provided in pairs, one at each end of the communication link.

[0057] The RLP protocol transits to the normal-mode as shown at 92, when certain implementation specific conditions are met. One example of such conditions is when the pending data size is greater than a specific threshold. It is to be understood that other conditions for transition from burst-mode to normal-mode may be imposed, according to the respective CoS.

[0058] Whenever the RLP protocol entity at one end decides to transit to the normal-mode, it starts an initialization handshake procedure. Once the handshake procedure is completed, peer RLP protocol entities (the paired RLPs) enter in the normal-mode of operation. Therefore, the transition is automatically synchronized between peer RLP protocol entities.

[0059] During the initialization handshake process, burst-mode operation is not allowed. For unacknowledged data burst sent out prior to the initialization handshake process, the RLP protocol entity resends the data burst after entering the normal-mode. Any data burst received during the initialization handshake process is discarded by the ARQ protocol entity.

[0060] Once in the normal-mode, the RLP protocol entity is not allowed to transit back to the burst-mode, since the peer protocol entity at the other end of the communication link is already synchronized.

[0061] When the RLP instance is released due to the MAC state machine transition to "dormant state", the RLP protocol is deactivated from both modes as shown at 93 and 94.

[0062] We should also note that other APQ methods may be used in the QoS data plane as defined by the present invention for optimizing the operation of the QoS data planes.

[0063] The PLDCF section contains the MUX&QoS module 34 which multiplexes various CoS RLP frames onto different physical channels. Based on their QoS requirements, MUX&QoS 34 transmits multiple service

type frames to the Physical Layer 20 (not shown) for Coding and Modulation (C&M).

[0064] The above description was made for the forward direction of transmission, i.e. from the transmitting side to the receiving side. It is to be understood that the operations are similar for the reverse direction.

[0065] At the receiving side, peer SAR modules (not shown) perform reassembly of the multiple Class of Service (CoS) frames received from a peer dedicated/common router (DCR) module (not shown).

Data Link Layer for UMTS

[0066] A wireless communication system has to support a packet switched data in a circuit switched environment. Previously, for DLL protocols, packet data sessions were defined based on different application sessions and resources were assigned to each of them. According to a preferred embodiment of the present invention the incoming traffic is considered a combination of different IP flows with different QoS requirements (or Classes), called subflows. Thus, the packet data application sessions/flows is replaced with QoS subflows. Irrespective of the application which generated the IP flow, the flow is categorized based on the QoS requirements, or the CoS.

[0067] It is to be noted that prior art methods have to undo all the higher layers framing and to duplicate all the QoS classifications done at the higher layers in order to differentiate among different applications, and this is contrary to the layering scheme strategy.

[0068] Figure 6 shows the UMTS radio interface protocol architecture layer proposed for a 3G wireless network and is reproduced from the Third Generation Partnership Proposal Technical Specification 25.301 (3GPP TS 25.301).

[0069] Layer-1, or the Physical Layer 20 of the UMTS radio interface is responsible for coding and modulation of data transmitted over the air.

[0070] Layer-2, or the Data Link Layer 30 is subdivided into a Radio Link Control (RLC) sublayer 70 and the Medium Access Control (MAC) sublayer 80. The separation in MAC 80 and RLC 70 sublayers is motivated by the need to support a wide range of upper layer services, and also the requirement to provide high efficiency and low latency data services over a wide performance range, i.e. from 1.2 Kbps to greater than 2 Mbps. Other motivators are the need for supporting high QoS delivery of circuit and packet data services, such as limitations on acceptable delays and/or data BER (bit error rate), and the growing demand for advanced multimedia services. Each multimedia service has different QoS requirements. Data Link Layer 30 also comprises a C-Plane Signalling and a U-Plane Information for separating the information from control signals.

[0071] The RLC 70 of the radio interface protocol architecture 100 for the UMTS shown in Figure 6, receives data packets from the higher layers, such as IP, through Service Access Points (SAP) 13, and delivers RLC frames to the MAC sublayer 80. The RLC frames are queued into logical channels 15. At the MAC sublayer 80, the RLC frames are multiplexed onto transport channels 25. The transport channels 25 are the interface of the Physical Layer 20 to the Data Link Layer 30. In fact, Data Link Layer 30 functions are divided in two parts, Physical Layer Independent Convergence Function (PLICF) handled in the RLC 70, and Physical Layer Dependent Convergence Function (PLDCF) included in the MAC 80. It is assumed that there is one instance of RLC 70 for each data application/session.

[0072] Figure 7 illustrates the DLL protocol according to a preferred embodiment of the invention which includes direct support for the IP protocol and isolates the logical operation of the Network Layers from the Physical Layer 20. The structure of the Data Link Layer 30 shown in Figure 7, is designed to support IP networking without adding any limitations that are not related to the wireless systems. The new Data Link Layer 30 design may be viewed as an interface between the IP layer and the Physical Layer 20, and can accommodate a variety of Classes of Service (CoS) having different Quality of Service (QoS) requirements.

[0073] As indicated before, the IP packets 45 include the IP Quality of Service (IPQoS) information. The DLL protocol 100 has a scheme to map the IPQoS requirements to Classes of Service (CoS). Each CoS is separated inside the DLL 30 and directed to a dedicated QoS plane.

[0074] The architecture of Figure 7, comprises a subflow processing module 71 for receiving the IP packets through check point 11 and redirecting the IP packets 45 to different instances of the QoS planes (1...n). The subflow processing module 71 checks the IP packets 45 and categorizes them into different subflows, or equivalently QoS planes (1...n). For example, if the Duff-Serv method is used, the subflow processing module 71 may simply peak into the IP packets 45 to map the QoS requirements, or CoS included in the IP packet 45 to one of the QoS planes (1...n) in the RLC 70. If the Int-Serv is used, the subflow processing module 71 involves in the RSVP, or any admission protocol, and redirects each IP packet 45 to one of the QoS planes (1...n) based on the agreed QoS requirements. It is to be noted that there is one dedicated subflow processing module 71 for each User Equipment (UE).

[0075] Each QoS plane (1..n) is configured to handle a CoS or equivalently a range of QoS requirements. Each QoS plane (1.. n) includes a Data-RLCs (D-RLC) (14-1 ... 14-n) and its associated Control-RLCs (C-RLC) (12-1...12-n). As shown before, the D-RLCs (14-1...14-n) and C-RLCs (12-1...12-n) receive the IP data packets 45, create the RLC PDUs, or RLC frames and deliver the RCL frames over logical channels 15 to the MAC sublayer 80 to be multiplexed onto different transport channels 25.

[0076] The inclusion of an associated Control-RLC

12 is necessary because data are handled based on their QoS requirements and consequently, the associated control signals must be treated at least the same to meet those requirements. For example, it is not acceptable to send control signals associated with a higher priority to propagate data with a lower priority traffic. This may result in violation of proper treatment of the QoS requirements corresponding to the transmitted data. Still, increasing the priority of the Control-RLC 12 to indirectly increase the priority of associated data, is permitted. This is especially important in the case where control signals are needed to insure connectivity, although the data might be sent as in the best effort delivery.

[0077] In contrast with the fixed Radio Link Protocols (RLPs) defined for the "cdma2000" standard, the RLCs are totally re-configurable, i.e. the segment size, the number of retransmission, etc. Thus, QoS planes (1...n) are also reconfigurable to fit a corresponding CoS.

[0078] There are a number of entities inside a QoS plane (1...n) that can be dynamically reconfigured, or fine tuned and optimized to meet specific QoS requirements of a CoS. This includes, segment size at the Segmentation, Concatenation and Reassembly (SCR) module of the RLC, resource assignments, logical channel to transport channel mapping, priorities, etc. Moreover, the type of the error recovery method used in each QoS plane (1...n) varies and depends on the QoS requirements in that particular plane.

[0079] Figure 8 illustrates the process of mapping the received IP packets 45 into RLC PDUs, or RLC frames according to the DLL protocol 100. As discussed before in connection with Figure 7, the subflow processing module 71 is responsible for receiving the IP packets 45 and extracting the IP QoS requirements included in each packet. IP QoS requirements are translated into classes of service (CoS) The subflow processing module 71 also initiates a QoS plane (1... n), or subflow, for each CoS under the supervision of a Radio Resource Control (RRC) unit 44. Each QoS plane (1...n) includes dedicated D-RLC and (14-1...14-n) and C-RLCs (12-1...12-n) instances.

[0080] Based on the QoS classification obtained, the QoS subflow processing module 71 redirects the IP packets 45 to the proper QoS plane (1...n). Packets without IP QoS classification are defaulted to a "best effort" data plane. It should be noted that any network layer protocol other than the IP may be supported by including the corresponding functionality in the QoS subflow processing module 71. There is one corresponding QoS subflow processing module 71 for each User Equipment (UE). Moreover, the receiving and the transmitting ends comprise identical QoS planes (1...n).

[0081] The method of generating radio link control protocol data units (RLC PDUs), or RLC frames will be now discussed in connection with RLC frame 77. As shown in Figure 8, an optional length (LEN) indicator 47 is added to each IP packet 45 by the subflow processing module 71. The length indicator 47 is added to enable reconstruction of the original IP packet 45 by a Segmentation, Concatenation and Reassembly (SCR) module which is part of the RLC at the receiving side (not shown). In the case when the length indicator of the IP header is used, the LEN indicator 47 is not needed. In any event, the resulting packet 46 is called an "augmented IP packet".

[0082] The SCR module of the D-RLC (14-1...14-n) chops the augmented IP packet 46 into smaller size packets, which are more suitable for error recovery and retransmission. These smaller size packets, or "sequence frames" are denoted with 74, on Figure 8. The size of a sequence frame 74 may be variable and dynamically optimized in different QoS planes (1...n), based on the QoS requirements and on the radio link conditions.

[0083] A start of message (SOM) bit field 75 and a sequence number field 76 are then added to the payload 46. A logic "1" for example in SOM bit 75 could be used to identify the start of the sequence frame 74. The sequence number is necessary in the retransmission of unsuccessful frames.

[0084] A QoS field 73 is also added to each sequence frame 74 to differentiate various frames directed to different QoS planes (1...n). This field is denoted as "QoS" in Figure 7, and contains the QoS plane number of the frame. This information is necessary for the multiplexing/demultiplexing process performed between peer Medium Access Control (MAC) layers. Specifically, field 73 is needed at the MAC sublayer at the receiving end for redirecting the received frames to the proper QoS plane.

[0085] One important feature in the SCR module (which is part of the RLC), is the "concatenation" of short data messages. In the case where the amount of data in each IP packet 45 is very small with respect to the size of the RLC PDU 77, i.e. a 10 ms frame load, the SCR module concatenates a number of short messages into one RLC frame 77. This is a subframing process performed at the Link Layer 30 level, is called "multiframing".

[0086] A frame check sequence (FCS) 79 and flags 68 and 78 may be added. The RLC frame 77 are then delivered to the MAC instances over the logical channels 15.

[0087] The point-to-point link connectivity of each QoS plane (1...n) is maintained by peer RLC instances located at both the transmitting and the receiving sides.

[0088] The RLC Protocol Data Units (RLC-PDUs), or RLC frames 77 are delivered to the MAC sublayer 80 to be multiplexed onto different transport channels 25 and prioritized based on their QoS requirements. The Radio Resource Control (RRC) module 44 controls this operation.

[0089] In the receiving side, the MAC sublayer demultiplexes the received frames and redirects them to

corresponding QoS planes based on their QoS plane number field 73.

[0090] A Data Link Layer (DLL) 20 protocol for direct support of the Internet Protocol (IP) networking in the Universal Mobile Telecommunications System (UMTS) 100, is provided. The disclosed Data Link Layer 20 comprises a Radio Link Control (RLC) 70 sublayer and a Medium Access Control (MAC) 80 sublayer At a transmit end, as well as at a receiving end of the UMTS wireless system 100, a plurality of Quality of Service (QoS) planes 1...n are created according to IP QoS requirements. At the RLC level, each QoS plane 1...n comprises a Data-RLC 14-1,..., 14-n and a Control-RLC 12-1, ..., 12-n. The QoS planes 1...n are optimized to handle the QoS requirements of a corresponding Class of Service (CoS). At the transmitting end, the data packets received from the upper layers are directed to a QoS plane according to the particular QoS information they contain, and processed according to their particular QoS requirement. A Segmentation, Concatenation, and Refraining module (SCR) is used to generate variable size RLC frames 77; 77', including multiframing. The variable size RLC frames 77; 77' are transmitted to the MAC sublayer 80 using logical channels 15. At the MAC sublayer 80, the RLC frames 77; 77' are multiplexed onto transport channels 25 based on their QoS requirements and transmitted to the physical layer for propagation to the receiving end.

[0091] According to the invention, the IP layer can sit on top of the new Data Link Layer 20 and the DLL protocol 100 provides direct support for any network layer protocol with no need for any additional protocol as an interface. This greatly reduces the limitations imposed by other protocols, which are not designed for the wireless systems.

[0092] The above description was made for the forward direction of transmission, i.e. from the transmitting end to the receiving end. It is to be understood that the operations are similar for the reverse direction.

[0093] Numerous modifications, variations, and adaptations may be made to the particular embodiments of the invention described above without departing from the scope of the invention defined in its claims.

Claims

1. A Data Link Control (DLC) protocol for direct support of a network layer protocol, comprising:

    at a transmit end of a wireless communication system:

        a plurality of Quality of Service (QoS) data planes, a QoS data plane for processing a QoS oriented data packet according to a class of service (CoS), and to provide a radio link protocol data unit (RLP PDU);
        a QoS processing module for receiving a network layer protocol data packet, converting said network layer protocol data packet into said QoS oriented data packet, and directing said QoS oriented data packet to one of said QoS data planes according to QoS information in said network layer protocol data packet; and
        an interface between said DLC and a physical layer for receiving said RLP PDU and transmitting same to said physical layer.

2. A DLC protocol as claimed in claim 1, wherein each said QoS data plane comprises:

    a Link Access Control (LAC) protocol instance for receiving said QoS oriented data packet and generating a HDLC-like LAC frame; and
    a Medium Access Control (MAC) protocol instance for receiving said LAC frame and generating said RLP PDU.

3. A DLC protocol as claimed in claim 2, wherein said LAC protocol instance comprises:

    a segmentation and re-assembly (SAR) module for receiving said service oriented data packet and dividing same into a number of sequence frames; and
    a framing and automatic repeat request (ARQ) module for receiving said sequence frames and encapsulating a plurality of said sequence frames into said LAC frame.

4. A DLC protocol as claimed in claim 2 or 3, wherein said MAC protocol instance comprises:

    a dedicated/common router (DCR) for receiving and routing said LAC frames to be carried over a radio traffic channel; and
    a radio link protocol (RLP) for receiving said LAC frames and converting said LAC frames into said RLP PDUs.

5. A DLC protocol as claimed in claim 4, further comprising a MAC control state machine (CSM) for regulating the delivery of said LAC frames to said RLP.

6. A DLC protocol as claimed in claim 4 or 5, wherein said RLP comprises an automatic repeat request (ARQ) function for automatic retransmission of said RLP PDUs if received in error at a receiving end of said wireless system.

7. A DLC protocol as claimed in claim 6, wherein said ARQ function has a selective repeat component active during a normal-mode (NM) of operation and a stop and wait (SW) component active during a burst-mode (BM) of operation.

8. A DLC protocol as claimed in any one of claims 3 to 7, wherein said LAC frame has a variable size, said size being dynamically optimized based on the conditions of the communication link.

9. A DLC protocol as claimed in claim 8, wherein said size of said LAC frame is automatically reduced: i) when a predetermined number of negative acknowledgments (NAK) are received, or ii) if no acknowledgments are received for a predetermined period of time.

10. A DLC protocol as claimed in any preceding claim, wherein said interface is a multiplexer for receiving said RLP PDU, and multiplexing same into a physical channel according to the QoS of said RLP PDU, for transmission to a receiving end of said wireless system.

11. A DLC protocol as claimed in any preceding claim, further comprising a resource control unit for mapping a QoS requirement to a DLC class of service (CoS), and separating said CoS inside the DLC protocol into said QoS data planes.

12. A method for direct processing a network layer protocol data packets for transmission over a wireless communication system, comprising the steps of:

separating the data link layer of the wireless communication system into a plurality of Quality of Service (QoS) data planes, a QoS plane for processing a QoS oriented data packet according to a class of service (CoS), and to provide a radio link protocol data unit (RLP PDU);
processing said network layer protocol data packet by converting said network layer protocol data packet into said QoS oriented data packet and directing said QoS oriented data packet to one of said QoS data planes according to QoS information in said network layer protocol data packet; and
forwarding said RLP PDU to a physical layer according to the QoS of said RLP PDU.

13. A method as claimed in claim 14, wherein said step of separating comprises:

providing a plurality of QoS oriented Link Access Control (LAC) protocol instances, a LAC protocol instance for each said QoS data plane, said LAC protocol instance for receiving said service oriented data packet and generating a HDLC-like LAC frame; and
providing a plurality of QoS oriented Medium Access Control (MAC) protocol instances, a MAC protocol instance for each QoS data plane, said MAC protocol instance for receiving said LAC frames and generating said radio link protocol data unit (RLP PDU).

14. A method as claimed in claim 13, wherein said step of generating a HDLC-like LAC frame comprises dividing said QoS oriented data packet into a number of sequence frames and encapsulating a plurality of said sequence frames into said LAC frame.

15. A method as claimed in claim 13 or 14, wherein said step of generating said RLP PDU comprises receiving said LAC frames and converting said LAC frames into said RLP PDUs.

16. A method as claimed in claim 15, further comprising regulating the delivery of said LAC frames to said RLP.

17. A method as claimed in claim 13, 14, 15 or 16, further comprising an automatic repeat request (ARQ) function for automatic retransmission of said RLP PDUs if received in error at a receiving end of said wireless system.

18. A method as claimed in any of claims 12 to 17, wherein said step of processing comprises mapping a QoS requirement to a DLC class of service (CoS), and separating said CoS inside the DLC protocol into said QoS data planes.

19. A method as claimed in claim 18, wherein said step of processing further comprises adding a length indicator to said network layer protocol data packet.

20. A Data Link Layer (DLL) protocol for direct support of a network layer protocol in the Universal Mobile Telecommunications System (UMTS), comprising:

at a transmitting end of the UMTS,

a plurality of Quality of Service (QoS) planes, a QoS plane for processing a QoS oriented data packet according to a Quality of Service (QoS) requirement, and to provide a radio link control (RLC) frame;
a subflow processing module for receiving a network layer protocol data packet, converting said network layer protocol data packet into said QoS oriented data packet, and directing said QoS oriented data packet to one of said QoS planes according to QoS information in said network layer protocol data packet; and
an interface between said Data Link Layer and a physical layer for receiving said RLC and transmitting same to said physical

layer.

21. A DLL protocol as claimed in claim 20, wherein each said QoS plane comprising:

a Radio Link Control (RLC) instance for receiving said QoS oriented data packet and generating a RLC frame; and
a Medium Access Control (MAC) instance for receiving said RLC frame over logical channels and multiplexing said RLC frames onto transport channels.

22. A DLL protocol as claimed in claim 21, wherein said RLC instance comprising a Data-RLC instance and a Control-RLC instance.

23. A DLL protocol as claimed in claim 22, wherein said Data-RLC instance comprising a segmentation, concatenation and reframing (SCR) module for receiving a plurality of said QoS oriented data packet, dividing same into sequence frames, and generating said RLC frame.

24. A DLL protocol as claimed in claim 23, wherein said RLC frame has a variable size, said size being dynamically optimized based on the conditions of the communication link.

25. A DLL protocol as claimed in any of claims 21 to 24, wherein said MAC instance comprising a multiplexer for receiving said RLC frame and multiplexing same onto a transport channel according to said QoS requirement for transmission to said physical layer.

26. A DLC protocol as claimed in any of claims 21 to 25 further comprising a radio resource control (RRC) module for controlling said subflow processing module and the delivery of said RLC frames to said physical layer over said transport channels.

27. A DLL protocol as claimed in claim 26, wherein said radio resource control (RRC) unit also for controlling the mapping said QoS requirement to a class of service (CoS) inside the DLL protocol.

28. A DLL protocol as claimed in any of claims 21 to 27, wherein said interface is a multiplexer for receiving said RLC frame from said QoS plane, and multiplexing same into said transport channels.

29. A DLL protocol as claimed in any of claims 20 to 28, wherein said QoS plane is totally reconfigurable and accepts various types of error recovery selected according to said QoS requirement.

30. A DLL protocol as claimed in any of claims 20 to 29, further comprising identical said QoS planes and said subflow processing module at the receiving end of the UMTS.

31. A method for direct processing a network layer protocol data packets for transmission over the UMTS wireless communication system, comprising the steps of:

separating the radio link control layer of the wireless communication system into a plurality of Quality of Service (QoS) planes, a QoS plane for processing a QoS oriented data packet according to a QoS requirement, and generating a radio link control (RLC) frame;
processing said network layer protocol data packet by converting said network layer protocol data packet into said QoS oriented data packet and directing said QoS oriented data packet to one of said QoS planes according to QoS information in said network layer protocol data packet; and
forwarding said RLC frame to a physical layer over a transport channel.

32. A method as claimed in claim 31, wherein said step of separating comprising:

providing a plurality of Radio Link Control (RLC) instances, a RLC instance for each said QoS plane, said RLC instance for receiving said QoS oriented data packet and generating said RLC frame; and
providing Medium Access Control (MAC) instances for receiving said RLC frames and multiplexing same onto said transport channels.

33. A method as claimed in claim 31 or 32, wherein said step of processing comprising mapping said QoS requirement to a class of service (CoS), and separating said CoS inside the DLL protocol into said QoS planes.

34. A method as claimed in claim 33, wherein said step of processing further comprising dividing said QoS oriented data packet into smaller sequence frames and refraining same into said RLC frame.

35. A method as claimed in claim 34, wherein said step of processing comprising adding a length indicator, a beginning of frame field, a sequence number field, and a QoS plane number to said network layer protocol data packet.

36. A method as claimed in any of claims 31 to 35, wherein said step of generating said RLC frame provides a dynamic optimization of the size of said

RLC frame based on the conditions of the communication link, for enhancing the quality of the air transmission.

37. A method as claimed in any of claims 31 to 36, comprising regulating the delivery of said RLC frames to said physical layer over said transport channel.

38. A method as claimed in any of claims 31 to 37, wherein the step of processing comprising multiframing.

39. A method as claimed in any of claims 12 to 19 or 31 to 38 or the DLC protocol of any of claims 1 to 11 or the DLL protocol of any of claims 20 to 30, wherein said network layer protocol is Internet Protocol (IP).

FIGURE 1A (Prior Art)

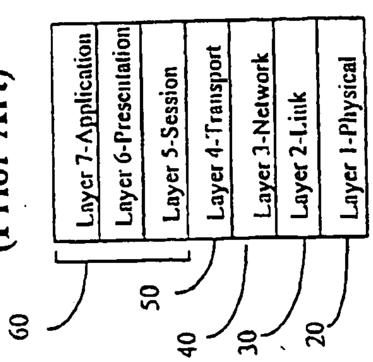


FIGURE 1B (Prior Art)

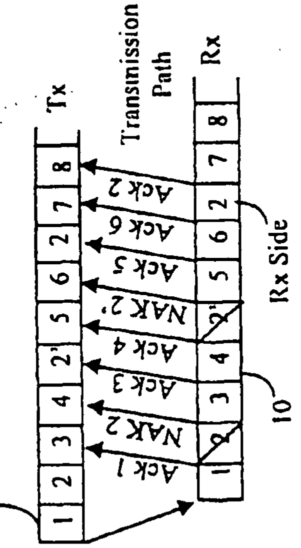


FIGURE 1C (Prior Art)

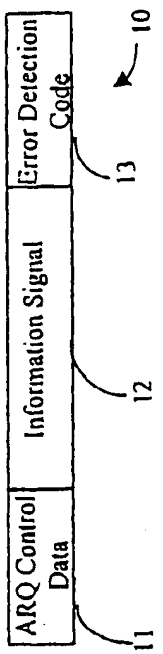


FIGURE 2 (Prior Art)

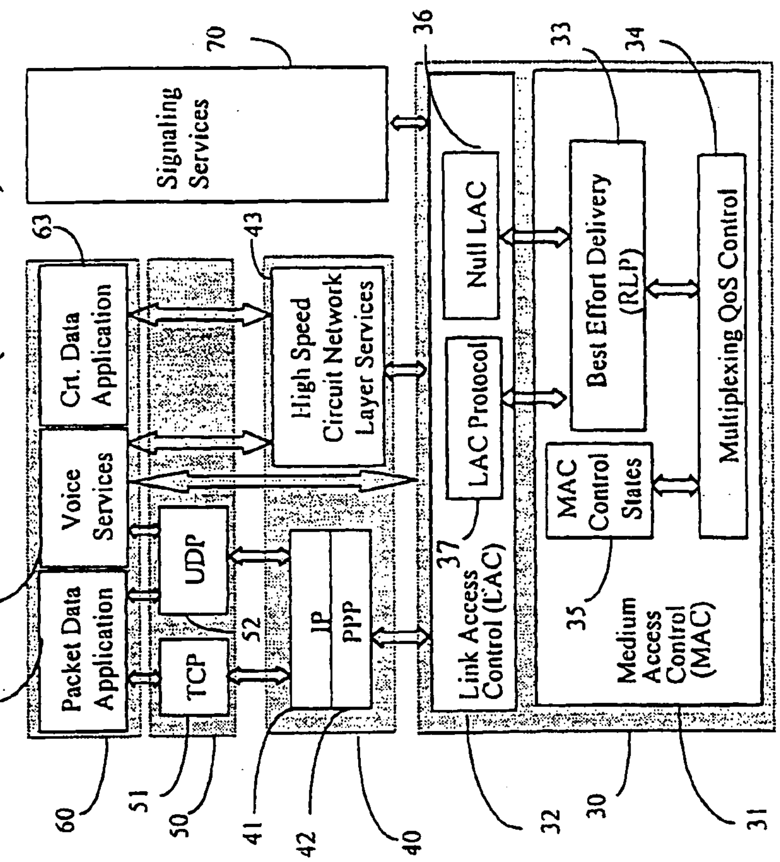


FIGURE 3

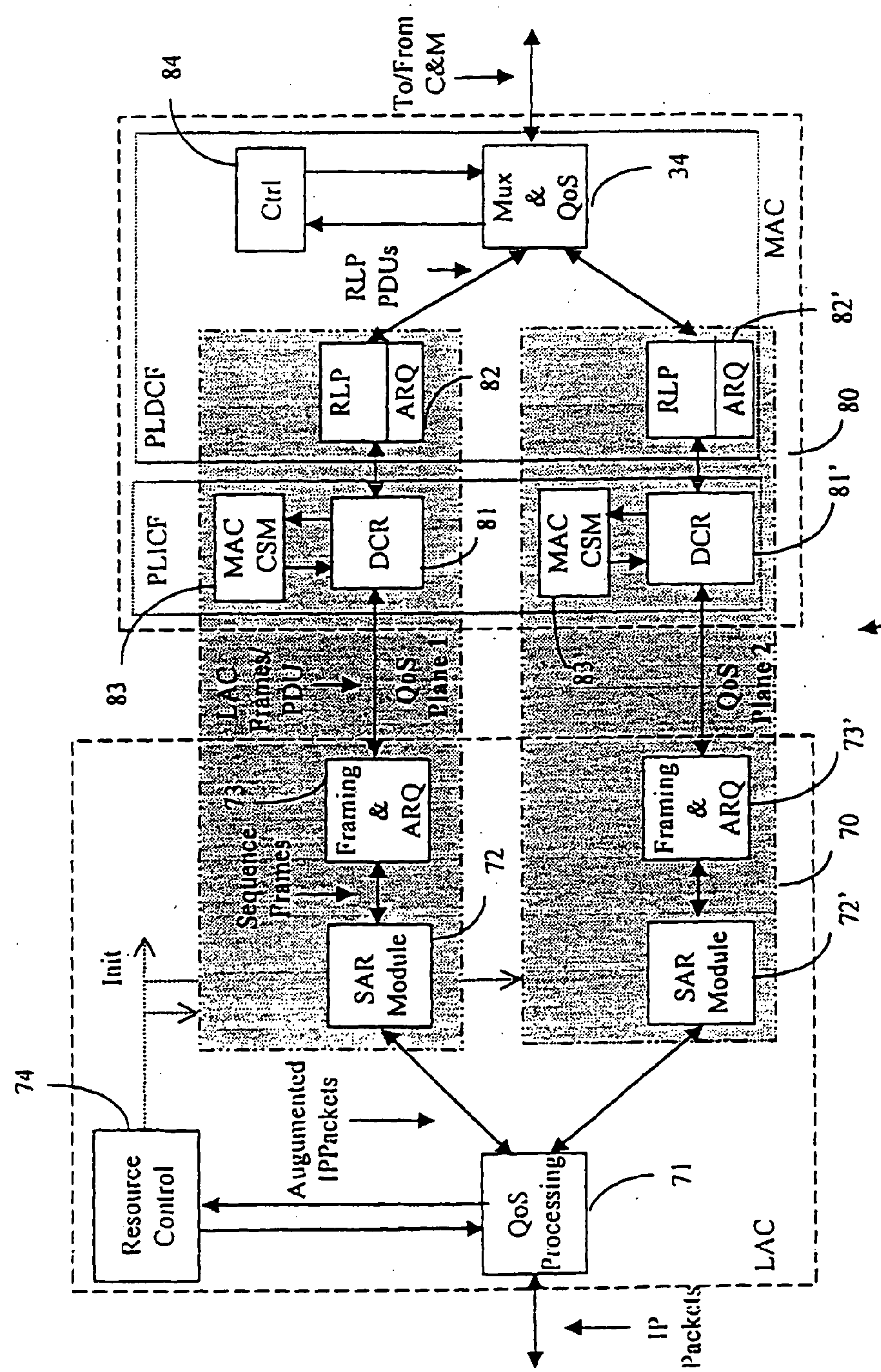
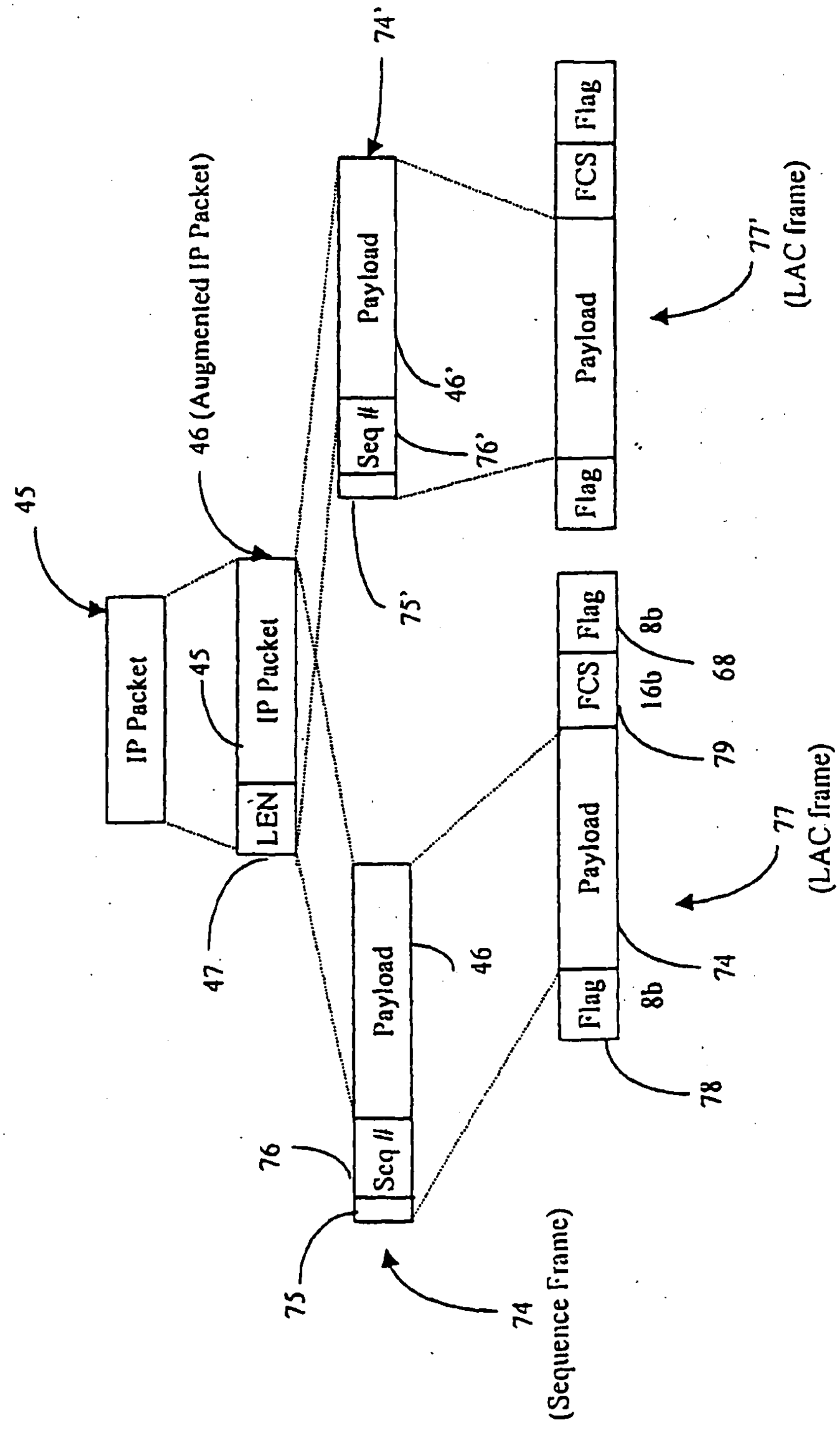

To/From C&M
84
Ctrl
Mux & QoS
34
RLP PDUs
MAC
PLDCF
RLP
ARQ
82
82'
80
PLICF
MAC CSM
DCR
81
81'
100
83
83'
LAC Frames/ PDU
QoS Plane 1
QoS Plane 2
Framing & ARQ
73
73'
Sequence Frames
SAR Module
72
72'
70
Init
74
Resource Control
Augumented IPPackets
QoS Processing
71
LAC
IP Packets

FIGURE 4


45
IP Packet
46 (Augmented IP Packet)
LEN
IP Packet
45
47
Seq #
Payload
76
75
46
74
(Sequence Frame)
Flag
Payload
FCS
Flag
8b
16b
8b
78
74
79
68
77
(LAC frame)
74'
Seq #
Payload
75'
76'
46'
Flag
Payload
FCS
Flag
77'
(LAC frame)

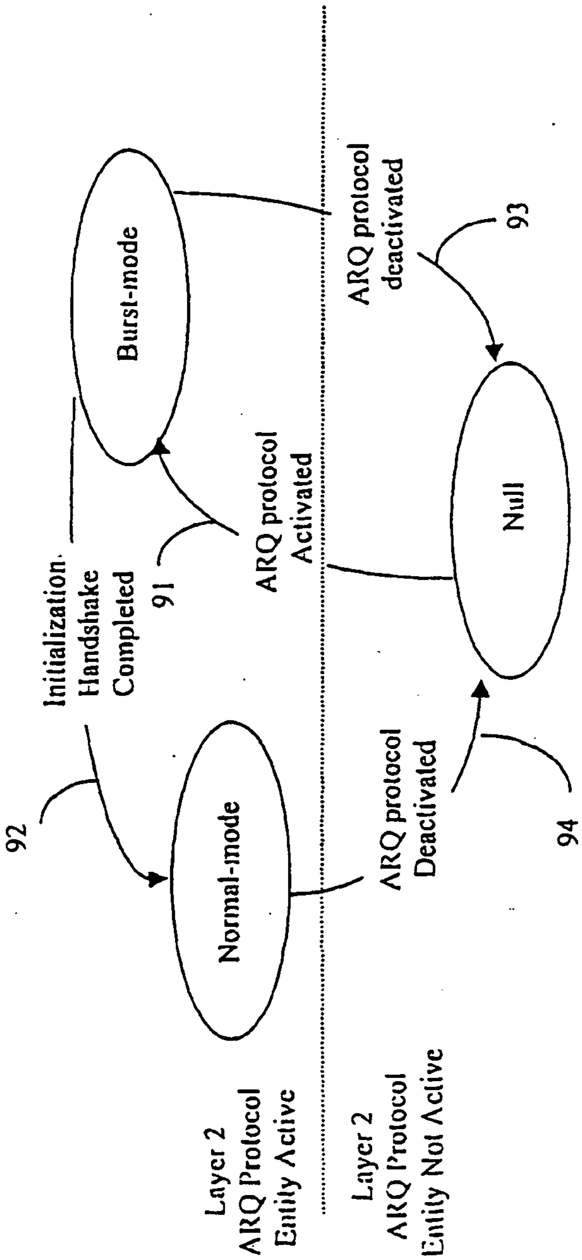

Layer 2
ARQ Protocol
Entity Active
Layer 2
ARQ Protocol
Entity Not Active
Normal-mode
Burst-mode
Null
Initialization
Handshake
Completed
92
91
ARQ protocol
Activated
ARQ protocol
deactivated
93
ARQ protocol
Deactivated
94

FIGURE 5

FIGURE 6(Prior Art)

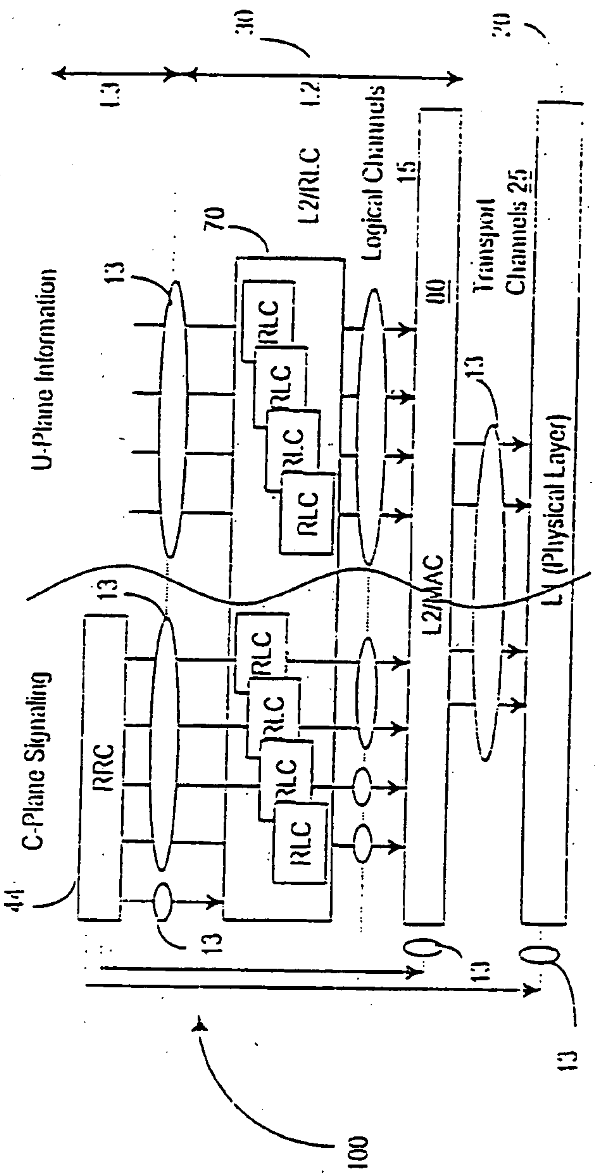


FIGURE 7

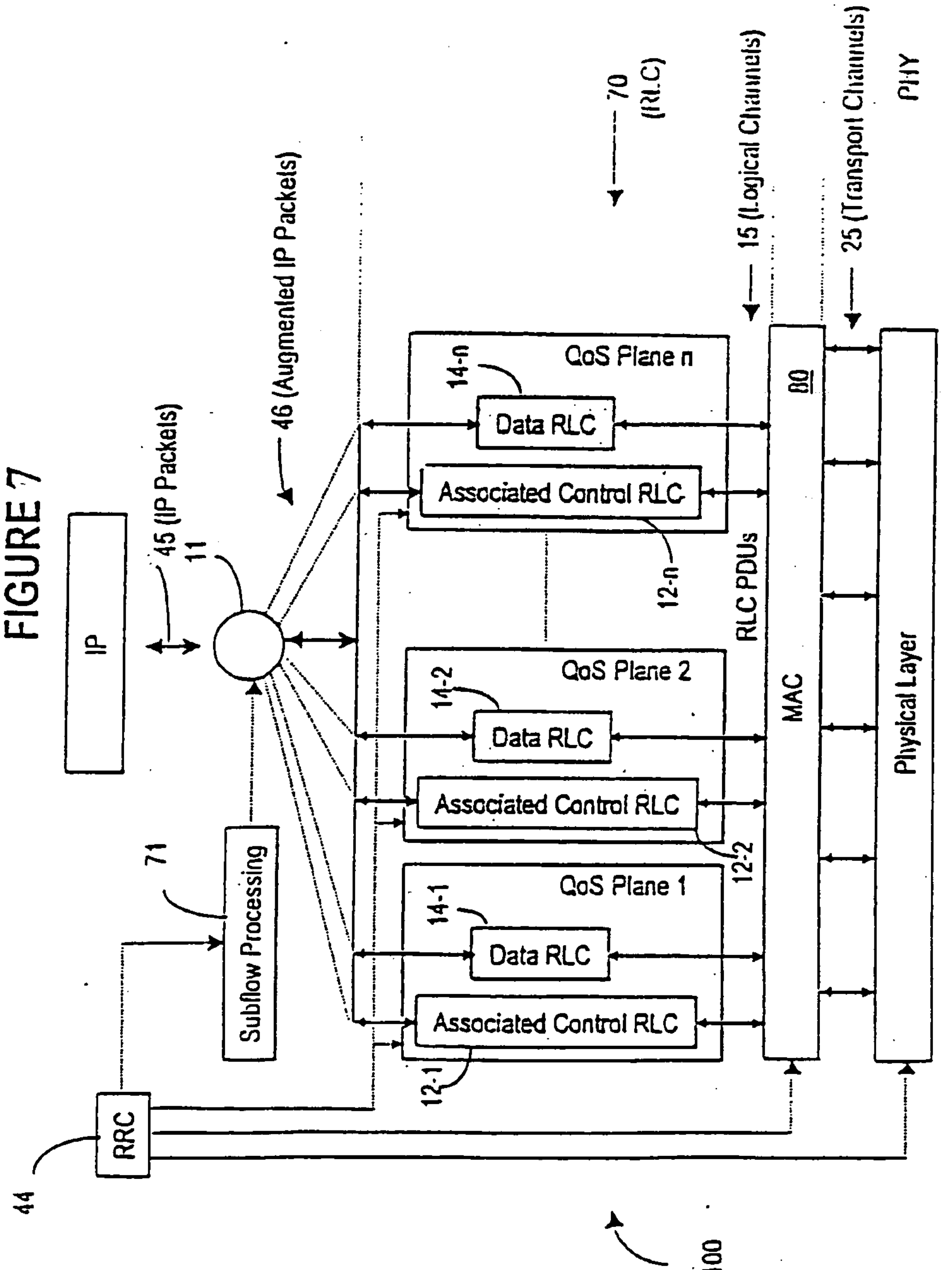
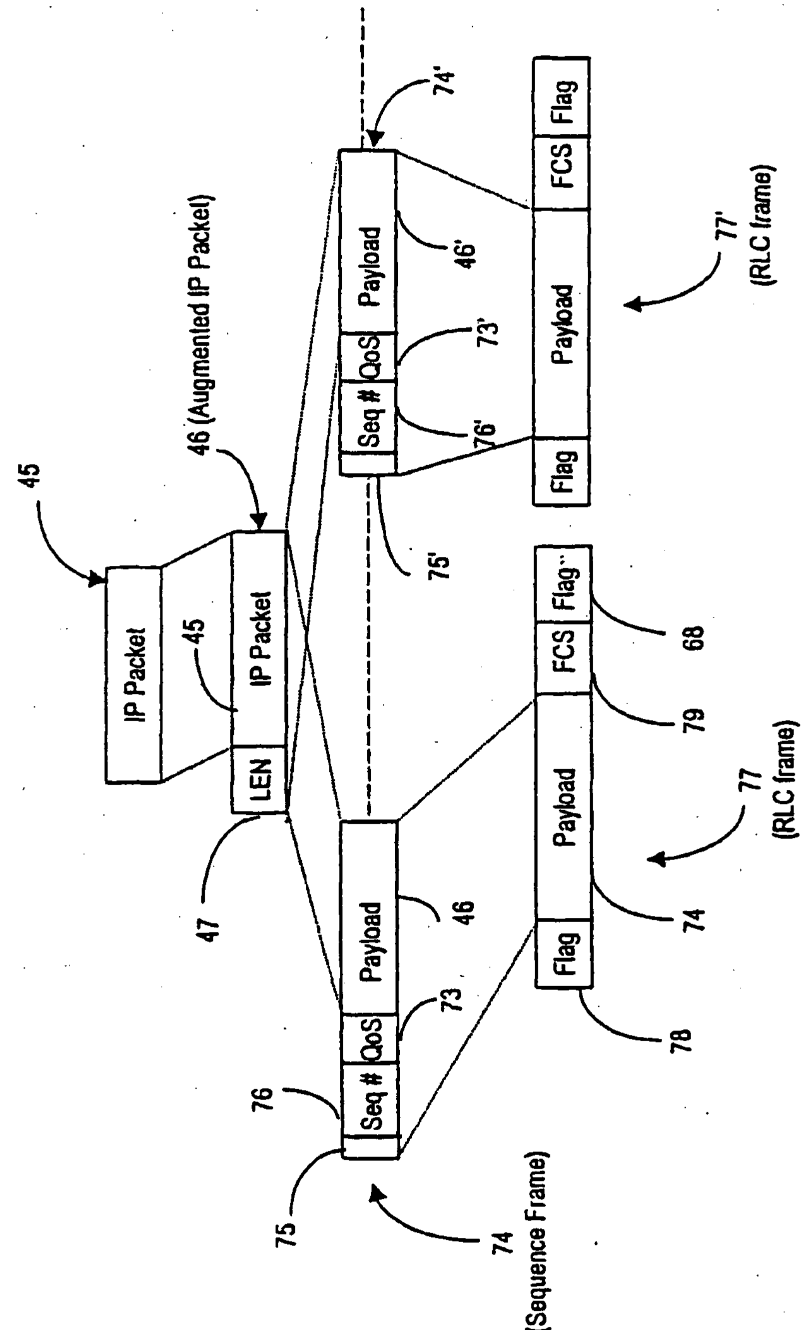

IP
45 (IP Packets)
11
46 (Augmented IP Packets)
70
(RLC)
15 (Logical Channels)
25 (Transport Channels)
PHY
71
Subflow Processing
QoS Plane n
14-n
Data RLC
Associated Control RLC
12-n
QoS Plane 2
14-2
Data RLC
Associated Control RLC
12-2
QoS Plane 1
14-1
Data RLC
Associated Control RLC
12-1
RLC PDUs
80
MAC
Physical Layer
RRC
44
100

FIGURE 8


45
IP Packet
46 (Augmented IP Packet)
45
IP Packet
LEN
47
74'
Seq #
QoS
Payload
46'
73'
76'
75'
Flag
Payload
FCS
Flag
77'
(RLC frame)
75
76
Seq #
QoS
Payload
73
46
74
(Sequence Frame)
Flag
Payload
FCS
Flag
78
74
79
68
77
(RLC frame)